Trends in Stroke Survival Incidence Rates in Older Australians in the New Millennium and Forecasts into the Future

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Aims: The objective of this study is (i) to evaluate trends in the incidence rates of stroke survivors aged 60 years and older over a 11-year period in the Australian Capital Territory (ACT) and (ii) to forecast future trends in Australia until 2051. **Methods:** Analysis of age- and sex-specific standardized incidence rates of older first-ever stroke survivors in ACT from 1999-2000 to 2009-2010 and projections of number of stroke survivors (NSS) in 2021 and 2051 using 2 models based only on (i) demographic changes and (ii) assuming changing of both incidence rates and demography. **Results:** In the ACT in the first decade of the 21st century, the absolute numbers and age-adjusted standardized incidence rates of stroke survivors (measured as a function of age and period) increased among both men and women aged 60 years or older. The trend toward increased survival rates in both sexes was driven mainly by population aging, whereas the effect of stroke year was more pronounced in men compared with women. The absolute NSS (and the financial burden to the society) in Australia is predicted to increase by 35.5%-59.3% in 2021 compared with 2011 and by 1.6- to 4.6-fold in 2051 if current only demographic (first number) or both demographic and incidence trends (second number) continue. **Conclusions:** Our study demonstrates favorable trends in stroke survivor rates in Australia in the first decade of the new millennium and projects in the foreseeable future significant increases in the absolute numbers of older stroke survivors, especially among those aged 70 years or older and men. **Key Words:** Stroke survivors—incidence rates—trends—projections—Australia.
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Introduction

Rising life expectancy and declining birth rates have resulted in unprecedented aging of the population worldwide. The continuing demographic transformation, with the oldest age group comprising the fastest growing segment of the population, will further increase the

proportion of seniors in coming years. Increasing age is the strongest risk factor for chronic diseases, including stroke, and dependency. Globally, stroke is projected to be at least until 2030 the second leading cause of mortality¹ and ranks between the third and the seventh cause of disease burden.²⁻⁴ Among an estimated 62 million stroke survivors worldwide,⁴ more than half are dependent on others for every day activities⁵⁻¹⁰ and about a third have severe disability or need institutionalization.¹¹

In Australia, between 1996-1997 and 2005-2006, the number of hospitalizations for stroke remained stable, and there was an annual reduction of 4.0% in mortality rate and of 2.2% in hospitalization rate.¹² On the other hand, the nonfatal proportion of stroke burden was significantly higher (45% in men and 37% in women) than previously estimated.¹³

Because the population is aging and stroke mortality is declining faster than stroke incidence,¹⁴⁻¹⁸ long-term survival after stroke may continue to improve.¹⁹ In the

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rapidly growing number of very old stroke patients, newer therapies (eg, thrombolysis) may be under-used,^{20,21} and the nonfatal burden of stroke-related disability in coming years is likely to rise despite advances in treatment of stroke. However, most epidemiological studies focus mainly on the incidence and mortality rates, whereas age- and sex-specific information regarding stroke survivors is limited and controversial. Little information exists on sex differences and future directions in age-specific incidence rates of stroke survivors, particularly among persons aged 60 years or older, the group in which most stroke events occur and which does not always receive adequate care.^{22,23} Moreover, divergent trends in stroke incidence for men and women were reported.^{14,24} Some researchers found a higher risk of serious cardiovascular events in older male stroke survivors,²⁵ whereas others concluded that over coming decades the societal impact of stroke in women will increase as the population ages.²⁶

Data on temporal trends and long-term projections of stroke survivors are essential for understanding, planning, and decision making in health-care policies, resource allocation, research, prevention, and treatment of this debilitating disease. Surprisingly, such information is still scarce and controversial.

The objectives of this study were to present (i) age- and sex-specific trends in the incidence rates of stroke survivors 60 years of age and over in an 11-year period from 1999-2000 to 2009-2010 in the Australian Capital Territory (ACT) and (ii) projections of future trends in Australia until 2051.

Methods

Study Sample

All strokes occurring in the ACT are treated (hospitalized) only in the Canberra and Calvary public hospitals that make this region an ideal place for population-based epidemiologic research. We used administrative databases to identify patients discharged with a diagnosis of stroke. We performed a retrospective screening of medical records of all suspected stroke cases in these 2 hospitals. Separations with a principal diagnosis of *International Classification of Diseases, 10th Revision (ICD-10-AM)* codes 160 through 164 were included in the data set. To prevent double counting, inter- and intrahospital transfers for the same event and readmission were identified by matching date of birth, patient ID number, and admission and separation dates and were excluded from this analysis. Thus, each stroke was counted only once and only if the patient was alive at the time of discharge. Although both patients with first-ever and recurrent strokes were included in the primary database, only the first event was included in the final analysis. Patients younger than 60 years were excluded in the present study. A "stroke survivor" was defined as a person discharged after a nonfatal stroke.

Stroke Classification

We used the World Health Organization standard definition of stroke. All stroke cases were identified with the first-listed ICD code. Cases were further categorized into subarachnoid hemorrhage (ICD-10-AM 160), intracerebral hemorrhage (ICH, ICD-10-AM 161-162), cerebral infarction (ICD-10-AM 163), and ill-defined (unspecified) stroke (ICD-10-AM 164).

Population Data

Population estimates were obtained from the Australian Bureau of Statistics (ABS).²⁷ The ACT in 2006 (the time of census) had a total population of 334,119 people (1.75% of 19.9 million Australians), of whom 96.3% were white, 1.2% indigenous, and 2.6% Asians, with 13.8% aged 60 years and older. Our study covered the period from July 1, 1999, until June 30, 2010. Over this 11-year period, there was a 13.5% increase in the total ACT population (women +13.8% and men +13.3%) with a shift toward higher age: a 50.4% increase in people aged 60 years or older (women +48.3% and men +53.0%) and a 86.8% increase in people aged 80 years or older (women +73.5% and men +113.1%). For Australia, the corresponding proportion figures were 15.5% (15.5%, 15.5%), 31.7% (28.3%, 35.7%), and 52.3% (42.9%, 70.0%). Population estimates from 2011 onward were obtained from the ABS population projection Series B that is based on the 2011 census and trends in fertility rates, life expectancy at birth, and migration and most closely reflects recent trends.

Statistical Analysis

Annual sex- and age-specific incidence rates (per 100,000 population) were determined using the population data obtained from population census of the ABS. Age- and sex-adjusted stroke survivor rates were estimated using the number of hospital discharges as the numerator and the ACT age and gender population data at mid-year as the denominator. In noncensus years, population estimates from ABS were used. The annual age- and sex-specific incidence rates of stroke survivors were based on the numbers in 5 age groups. Then we calculated incidence rates for 3 age groups: 60-69, 70-79, and 85 years or older. The rates were also determined for stroke subtypes (hemorrhagic, ischemic, and ill defined).

Furthermore, to look into the overall trend in incidence rates of stroke survivors, sex-specific age-standardized incidence rates were calculated by the direct method using the Australian 2006 population aged 60 years or older as the standard. To get age- and sex-adjusted rates, age- and sex-specific rates for each year were multiplied by the corresponding Australian population, which was then divided by the total Australian population of men and women. After standardization, any differences between

incidence rates of stroke survivors over the study period can be attributed neither to the aging of the population nor to different sex distribution and indicate effects of other factors.

We also estimated in each calendar year changes (%) in absolute number and sex-specific rates of stroke survivors compared with the previous year and calculated the mean sex-specific annual survivor rate changes (%) over the 11-year period (1999-2000 to 2009-2010). The secular changes in the incidence rates of stroke survivors over the study period were examined with a Poisson regression model in which time was considered an independent variable, whereas age and sex were covariates. The Poisson regression model used to estimate the number of stroke survivors (NSS) was

$$\text{NSS}(x_1; x_2) = e^{a + b_1 x_1 + b_2 x_2},$$

where x_1 is the age in years and x_2 the year of stroke occurrence.

The data were analyzed using the Stata software version 10 (StataCorp, College Station, TX). The level of statistical significance was set at 2-sided P value less than .05.

Projections

To project the NSS in 2021 and 2051, we applied age- and sex-specific incidence rates of stroke survivors to the Australian population projections (ABS Series B “medium” data). Two alternative scenarios were assumed in the analysis: (i) incidence rates would remain stable at the average level in the first decade of the 21st century and, thus, predictions are based solely on projected sex- and age-specific size of the population at risk and (ii) survival incidence rates would continue to change for the next 40 years at the same rate as during the study period, and therefore, predictions made take into account both factors changing incidence rates and demographic forecast. In this model, the age- and sex-specific incidence rates for 2021 and 2051 were estimated from the Poisson regression equations, and the forecast NSS were calculated multiplying by projected population figures for each age group according to sex. With both models, separate predictions for men and women and for 3 age groups (60-69, 70-79, and 80 years or older) were made. The study was approved by the ACT Health Human Research Ethics Committee.

Results

General Characteristics of the Stroke Population

From 1999-2000 to 2009-2010, in the ACT, there were 2228 first-ever stroke hospitalized patients (1111 men and 1117 women) aged 60 years and older, of whom 444 (19.93%) died (205 [18.5%] men and 239 [21.4%] women). From the analysis, we also excluded 150 recurrent stroke

events that occurred in 131 elderly patients (2-5 stroke events in each person). The final sample included 1784 discharged alive first-ever stroke patients aged 60 years or older.

Demographic characteristics, stroke type, and absolute NSS during the 11-year period in the ACT and incidence rates according to sex and age are presented in Table 1. Women were significantly older than men when sustaining their stroke (on average 2.7 years, $P < .001$) and half of them were 80 years or older. Most of the cases were classified as cerebral infarction (47.9%) and ICH (21.1%). Women more often had a subarachnoid hemorrhage, the least common stroke subtype; no difference in the incidence of other stroke subtypes between genders was observed. The distribution of stroke subtypes did not change over time (data not shown). Taking total number of elderly stroke survivors, men and women were near equal (female to male [F:M] ratio .97); however, among 60- to 69-year-old survivors, 62.3% were men (F:M ratio .60), whereas in the “80 years or older” group 55.0% were woman (F:M ratio 1.22). At the end of the study period, in 2010, the age group 80 years or older comprised 4.04% of the total ACT population (3.20% among men and 4.85% among women) and accounted for 44.5% of stroke survivors (39.4% among men and 49.8% among women).

Stroke survival incidence rates (per 100,000 person-years) increased with advancing age in both sexes exponentially and in all 3 age groups were significantly greater in men than in women (F:M ratio .58, .82, and .70, respectively). The mean standardized rate for men was 20.5% higher ($P = .0016$).

Temporal Changes in the Number of Stroke Survivors and Trends in Incidence Rates

The annual numbers and rates of stroke survivors aged 60 years or older during the 11-year study period are given in Figure 1. The absolute NSS, although varied with a marked drop in 2008, in general, steadily increased among both men and women. In the last 3 years (2007-2008 to 2009-2010) compared with the first 3 (1999-2000 to 2001-2002), the total NSS increased by 57.5% (from 369 to 581), in men by 73.0% (from 174 to 301), and in women by 43.6% (from 195 to 280). The in-hospital mortality decreased from 37.7% at the beginning of the study period to 18.7% at its end, on average an annual 3.8% decline. During the study period, the temporal sex-specific age-adjusted standardized incidence rates demonstrated a slight insignificant trend toward increasing. The mean annual percentage changes, despite the fluctuations across the study years, showed increases of 4.5% (95% confidence interval [CI]: -7.5 to 16.5) in total, 3.4% (95% CI: -7.5 to 14.3) in men and 7.6% (95% CI: -10.7 to 25.9) in women. In the last 3 years compared with the starting 3 years, the incidence rates in total increased on

Table 1. Demographic characteristics, stroke type, absolute number, and sex-specific age-adjusted standardized* incidence rates of stroke survivors aged ≥ 60 years in Australian Capital Territory (1999-2000 to 2009-2010)

	Women	Men	Total
Stroke survivors, n (%)	878	906	1784
Age, y (mean $\pm$ SD)	78.6 $\pm$ 8.7	75.9 $\pm$ 8.6	77.2 $\pm$ 8.7
Age groups			
60-69 y, n (%)	145 (16.5)	240 (26.5)	385 (21.6)
70-79 y, n (%)	296 (33.7)	309 (34.1)	605 (33.9)
≥ 80 y, n (%)	437 (49.8)	357 (39.4)	794 (44.5)
Types of stroke			
SAH, n (%)	46 (5.2)	19 (2.1)	65 (3.6)
ICH, n (%)	174 (19.8)	203 (22.4)	377 (21.1)
CI, n (%)	419 (47.7)	435 (48.0)	854 (47.9)
NS, n (%)	239 (27.2)	249 (27.5)	488 (27.4)
Incidence rates per 100,000 person-years (95% confidence interval)			
60-69 y	114 (94.0-136.9)	195 (168.6-224.4)	154 (130.6-180.3)
70-79 y	370 (333.2-409.7)	452 (411.3-495.7)	406 (367.5-447.5)
≥ 80 y	866 (809.3-925.7)	1234 (1166.1-1304.8)	1000 (939.0-1063.9)
Mean ($\pm$ SD)	371.3 $\pm$ 62.8	447.5 $\pm$ 56.9	402.1 $\pm$ 50.1

Abbreviations: CI, cerebral infarction; ICH, intracerebral hemorrhage; NS, stroke type not specified; SAH, subarachnoid haemorrhage.

*Standardized to 2006 Australian population.

average by 4.5% (from 375.70 to 392.57), but this was confined only to men (on average +12.9%, from 396.67 to 447.72).

Impact of Age and Time (Year) of Stroke

The influence of age and calendar stroke year on the number and incidence rates of stroke survivors in the 11-year period was further examined by Poisson regression analysis (Tables 2 and 3). These models explore the combined effects of age (in 5-year intervals) and the calendar period of stroke onset. Generally, the absolute NSS increased with increasing age (b_1) and time of stroke (b_2) by 3.3% and 5.9%, respectively (Table 2). However, stratification for sex revealed that changes related to these factors were different in men and women. The influence of age was larger in women than in men (5.0% versus 1.7%). The effect of calendar year of stroke (b_2), which also significantly and positively influenced the number of survivors, in contrast to age, was more prominent in men than in women (6.7% versus 5.1%). Taken together, among men, the increased NSS during the study period was more influenced by the calendar year of the stroke, than the age, whereas in women both factors have near an equal effect. Of note, the estimates by the Poisson regression model corresponded well with the observed data: in the 11-year period, the calculated and actual NSS for men as for women were practically equal. According to this model, the absolute NSS in the ACT is projected to increase in 2021, compared with 2010, by 93% (from 224 to 433), by 68.5% in women (from 111 to 187), and by 121% in men (from 113 to 250) with further 5.8-

4.6-, and 7.4-fold increases, respectively, in 2051 (reaching 2530, 855, and 1853 persons).

The incidence rates of stroke survivors in both sexes increased with aging and stroke year (Table 3) and, as would be expected, with a significantly greater influence of age than the time of stroke (in total by 8.8% and 1.9%, respectively). However, in men, the calendar year of the stroke influenced survival rates to a larger degree than in women (2.4% versus 1.3%), in whom the influence of age was slightly higher than in men (9.22% versus 8.96%). According to the model for the sex-specific incidence rates (Table 3), explained variances were very high (R^2 .84-.89).

Stroke Survivors Forecasts in Australia

Population changes (2011-2051)

Over the next 40 years, the Australian population is expected to continue to increase by 7.2% in 2021 and by 18.7% in 2051.²⁸ The population aged 60 years or older is estimated to increase 34.1% (+35.1% men and +33.3% women) by 2021 and 116.9% (+119.6% men and +114.5% women) by 2051. Importantly, the proportion aged 60 years or older in 2021 and 2051 compared with 2011 will increase from 20.7% to 26.0% and 38.0%, respectively, including aged those 60-69 years from 10.5% to 12.2% and 15.0%, aged 70-79 years from 6.2% to 8.8% and 12.0%, and aged 80 years or older from 4.1% to 5.0% and 11.0%, respectively. Among those aged 60 years or older, the proportion of persons aged 80 years or older is projected to increase from 19.9% in 2011 to 29.0% in 2051 and the F:M ratio in this age group will decrease from 1.55 to 1.29. These age- and sex-specific shifts

Figure 1. Trends in number (solid lines) and sex-specific age-adjusted standardized (to Australian 2006 population) incidence rates (dashed lines) of stroke survivors in Australian Capital Territory from 1999-2000 to 2009-2010.

toward the most elderly population with an increasing proportion of men are likely to be associated with a higher NSS and more severe disability (as stroke severity worsens significantly with increasing age^{29,30}).

Stroke survivors in 2021 and 2051

These data were generated under the assumptions that the incidence rates of stroke survivors for aged 60 years or older in the ACT region are reflective of the national Australian incidence rates of stroke survivors. The numbers of projected stroke survivors for the years 2021 and 2051 according to the 2 models are shown in [Table 4](#) and [Figure 2](#). In model 1, the projections are based only on demographic changes assuming that age- and sex-specific incidence rates of stroke survivors would remain the same over the next 40 years (average for 1999-2000 to 2009-2010 period for each age group). These forecasts suggest that in Australia, compared with 2011, the total NSS aged 60 years or older may increase by 35.5% in 2021 and by 161.4% in 2051, of which 82.0% in 2021 and 87.3% in

2051 will be aged 70 years or older, whereas 47.6% and 60.4% will be 80 years or older, respectively.

Finally, the gender distribution indicates that the F:M ratio among 60- to 69-year-old and 70- to 79-year-old stroke survivors will not change. However, for the first time among survivors aged 80 years and older, there also will be more men than women: the F:M ratio will decrease from 1.09 in 2011 to .98 in 2021 and to .90 in 2051.

The second model is based on changing of both incidence rates and demography. Assuming age- and sex-specific incidence rates dynamics similar to the 1999-2000 to 2009-2010 period and a population according to the forecast, the expected NSS aged 60 years or older would increase by 59.3% (by 86.8% in men and by 43.1% in women) to the year 2021 and by 436.1% (by 668.4% in men and by 384.3% in women) to 2051. The F:M ratio is estimated to be .89 in 2021 and .58 in 2051.

Of note, according to both models in 2021, the stroke survivors aged 70-79 years are predicted to have the

Table 2. Influence of age and calendar year on the number of stroke survivors during the 11-year period (1999-2000 to 2009-2010) in men and women (Poisson regression analysis)

	Women	Men	Total
Intercept	-102.948	-132.397	-117.123
Age (b_1)	.050544	.01726	.033224
SE (b_1)	.004185	.003917	.002843
P value	<.001	<.001	<.001
Year (b_2)	.050719	.066711	.058818
SE (b_2)	.010756	.010648	.007566
P value	<.001	<.001	<.001
R ²	.3174	.1416	.3181

largest increases (+54.5% in men and +51.4% in women by model 1; +94.6% and +67.5%, in men and women, respectively, by model 2), whereas in 2051, the greatest increases will occur in those aged 80 years or older. This is likely because of the fact that the baby-boom generations will reach age more than 70 at year 2021.

Comparisons of the estimates by models 1 and 2 illustrate the contribution from demographic and incidence changes to the projected numbers of stroke survivors and show how it varies between gender and age groups. In 2021, compared with 2011, of the 59.3% increases in total stroke survivors predicted by model 2, 23.8% may be explained by increasing incidence: 47.4% in men and 10.4% in women. Gender difference in the effect of increasing incidence can be observed in the 70- to 79-year-olds (40.1% versus 16.1%) and in those aged 80 years or older (38.8% versus 10.7%), but it is less prominent in the 60- to 69-year-olds (35.3% versus 23.1%). Understandably, the gender and age differences in the respective role of incidence changing become significantly higher to the projected numbers of stroke survivors in 2051. The rise in incidence rates will contribute to 2.7- of 5.4-fold increase in total stroke survivors (4.6- of 7.3-fold in men and 1.3- of 3.8-fold in women), to 2.1- of 3.8-fold in 60- to 69-year-olds (2.8- of 4.5-fold and 1.3- of 3.0-fold in

men and women, respectively), to 2.8- of 5.5-fold in 70- to 79-year-olds (3.8- of 6.6-fold and 1.7- of 4.0-fold), and to 1.2- of 4.4-fold in those aged 80 years or older (6.2- of 9.7-fold and 1.0- of 3.9-fold).

Economic Impacts

One way to evaluate the potential social and economic burden of increasing numbers of stroke survivors in the aging population is to quantify the costs. In Australia, the average costs in the first year were estimated at AU \$18,956 (US \$14,361).^{6,12} Applying these data to our projections indicates that expenses for stroke survivors during the first year may reach, according to the first scenario, AU \$445.9 million in 2021 and AU \$860.0 million in 2051 and, according to the second scenario, AU \$693.6 million and AU \$2.34 billion, respectively. Compared with 2011, in the first year after the event, stroke survivors will increase the financial burden by 116.8 million (35.5%) in 2021 and by 530.9 million (161.3%) in 2051 under the circumstances of model 1 and by 258.1 million (59.3%) in 2021 and 1.9 billion (436.2%) in 2051 under the circumstances of model 2.

Discussion

The main findings of this study are 3-fold: (i) in the ACT in the first decade of the new millennium, the absolute numbers and age-adjusted standardized incidence rates of stroke survivors (measured as a function of age and period) increased among both men and women aged 60 years or older; (ii) the trend toward increased survival rates in both sexes was driven mainly by population aging, whereas the effect of year of stroke was more pronounced in men compared with women; and (iii) the absolute NSS in Australia is predicted to increase by 35.5%-59.3% in 2021 compared with 2011 and by 1.6- to 4.6-fold in 2051 if current demographic (first number) or both demographic and incidence trends (second number) continue.

Stroke Survivor Trends in the First Decade of the 21st Century

The increase in elderly stroke survivors could be because of higher stroke incidence, declines in mortality, or both. Our observation of significantly decreasing in-hospital mortality (3.8% per year) is similar to the 4.0% annual reduction in stroke mortality rate in Australia between 1996-1997 and 2005-2006¹² and consistent with other studies. In past decades, data from high-income countries,^{3,8,15,16,31-38} including Australia^{12,39-42} and New Zealand,¹⁴ indicated that stroke incidence rates, case fatality, and mortality rates had fallen (for whites but not for blacks and other ethnic groups). However, other studies covering the last 2 decades in the same countries reported stable or even rising stroke incidence.^{17,19,43-49}

Table 3. Influence of age and calendar year on the incidence rates of stroke survivors (per 100,000 person-years) during the 11-year period (1999-2000 to 2009-2010) in men and women (Poisson regression analysis)

	Women	Men	Total
Intercept	-27.033	-47.6863	-38.903
Age (b_1)	.092183	.089552	.087671
SE (b_1)	.000808	.000675	.000739
P value	<.001	<.001	<.001
Year (b_2)	.012947	.023528	.019125
SE (b_2)	.001827	.001543	.001698
P value	<.001	<.001	<.001
R ²	.8361	.8774	.8931

Table 4. Forecast number of stroke survivors aged ≥ 60 years in Australia to 2021 and 2051 according to 2 models

Age group	Women			Men			Total			F:M ratio		
	2011	2021	2051	2011	2021	2051	2011	2021	2051	2011	2021	2051
Model 1 (incidence rates unchanged, similar to the average in the 1999-2000 to 2009-2010 period)												
60-69	1265	1604	2136	2132	2630	3635	3392	4244	5756	.59	.61	.59
70-79	2509	3798	5726	2791	4313	6515	5286	8081	12,196	.9	.88	.88
≥ 80	4571	5649	13,370	4199	5769	14,783	8681	11,198	27,418	1.09	.98	.90
Total	8345	11,051	21,232	9122	12,712	24,933	17,359	23,523	45,370	.91	.87	.85
Model 2 (incidence rates changed as during the 1999-2000 to 2009-2010 period)												
60-69	1559	2337	4716	2531	4016	11,460	4109	6390	15,743	.62	.58	.41
70-79	2423	4058	9727	3485	6783	21,440	5824	10,606	29,964	.70	.60	.45
≥ 80	7883	10,584	31,152	4718	8313	45,731	13,044	19,595	77,476	1.67	1.27	.68
Total	11,864	16,979	45,595	10,735	19,113	78,631	22,977	36,591	123,182	1.16	.89	.58

The absolute number of stroke events and prevalence did not decrease^{44,50} and even continue to rise.^{17,41} At the end of the past century, in several studies, the declining stroke mortality could not be explained by changes in stroke incidence.⁵¹⁻⁵³ Diverging trends in stroke mortality and incidence have been recently reported in the United States⁵⁴ and some European countries.⁴⁵ In Australia up to 2005-2006, the declines in deaths from stroke were about 2 times higher than reduction in hospitalizations (4.0% versus 2.2%).¹² It appears, therefore, that declining mortality rates as a result of improvements in prevention, acute stroke management, and therapy^{3,55,56} may had a significant effect on the NSS. The plausible and encouraging decline in stroke deaths occurred in parallel with demographic changes. Given that the elderly population who are those most at risk constitute the fastest growing segment of the population, it is not surprising that over the last 11-year period in the ACT, concomitant with declining stroke mortality, the absolute number and incidence rates of stroke survivors aged 60 years or older increased.

Some prior studies reported trends in stroke incidence only by period. Our study illustrates the advantage and importance when analyzing secular trends to use models that account age and time (calendar year) of stroke simultaneously. The age effect reflects mainly biological factors, whereas the period effect includes the influence of preventive and treatment procedures. This approach revealed that, in the ACT, the incidence rates of stroke survivors in the first decade of the 21st century were increasing in men and women positively influenced by both age and year of the stroke, but in men, the effect of time was more pronounced. The increase of stroke rates with age is a well-known phenomenon.⁵⁷ In our study, among stroke survivors, 49.8% of women and 39.4% of men were 80 years of age and older. The causes of sex differences in regard to the stroke year are less clear and likely to be multifactorial, indicating possible more effective control of cardiovascular risk factors and/or more intensive care management in the acute phase of the stroke

in men compared with women^{24,58-60} who are older and have greater comorbidity.⁶¹

Worldwide, stroke incidence and mortality rates are higher in men than in women, but more women are affected (because of greater longevity) and possibly are more severely ill with greater disability and dependency.^{11,57,58,61-67} Some studies report divergent trends in stroke incidence for men and women^{14,24} and a higher risk of serious cardiovascular events in older male stroke survivors.²⁵

With respect to the F:M ratio for the absolute NSS, our data in line with other reports⁶⁸ show a steep rise from .60 in the 60- to 69-year old to 1.22 among those aged 80 years or older. The F:M ratio for incidence rates also increases with aging, but the highest level occurs in the 70- to 79-year-old group (.58, .81, and .70 in the 3 age groups, respectively). The findings of higher stroke survivor rates among men compared with women aged 60-80 years in this study are consistent with several population-based studies of stroke incidence.^{8,11,66,69,70}

Future Trends and Implications

Future trends in absolute numbers of older stroke survivors are determined by population growth and aging, stroke incidence, and stroke mortality rates.

Because the observed variability in temporal incidence rates was a matter of concern in long-term projections, we concentrated on 2 models reflecting stable and increasing incidence rates of stroke survivors. Our data indicate a very significant increase in the future NSS in Australia and consequently a shift from a mortality burden toward a morbidity burden similar to that recently predicted for Western Europe.¹⁵

In Australia, the forecast based only on population growth and age-related changes indicates a 35.5% (39.4% in men and 32.4% in women) increase in stroke survivors in 2021 and 161.4% (154.4% and 173.3% in men and women, respectively) in 2051 compared with 2011. Importantly, more than 80% of stroke survivors

Figure 2. Forecast number of stroke survivors aged 60 years and older in Australia to 2021 and 2051 according to 2 models. In model 1, the projections are based on demographic changes assuming that age- and sex-specific incidence rates of stroke survivors would remain unchanged similar to the average in the 1999-2000 to 2009-2010 period. In model 2, the projections are based on changing of both incidence rates (as during the 1999-2000 to 2009-2010 period) and demography.

will be 70 years or older and about a half 80 years or older with a prevalence of men in all age groups. In Europe, solely because of the demographic changes, the annual number of strokes is predicted to increase from 1.1 million in 2000 to 1.5 million (+36.4%) in 2025.⁷¹ It is expected that the negative effect of stroke on life expectancy in 7 western European countries would strongly decline: in 2030, about .5 years in men and less than 1 year in women.¹⁵ Data presented in our conservative model 1 are comparable with estimates from Europe. Of note, in Australia, the number of surviving poststroke individuals tripled from 1996 to 2010.⁷²

According to the second model, which includes increases in incidence rates in addition to demographic changes, the projected number of older stroke survivors may increase by 59.3% in 2021 and by 436.1% in 2051. For men aged 70 years or older, the effect of increasing

rates on the total number of projected survivors in 2021 is 2.5 times (for 70- to 79-year-olds) to 3.8 times (for those aged 80 years or older) higher than in women; in 2051, the corresponding figures are 2.2 and 6.0 times. Both models suggest that the societal impact of stroke in older men will continue to increase (in all age groups, F:M ratio is less than 1.0, except for those aged 80 years or older in 2021 in model 2) indicating that it is necessary to pay more attention to stroke prevention in the elderly men, even though the stroke mortality is higher in women.

Taken together, these forecasts suggest that over the next few decades a very significant increase in numbers of older stroke survivors is to be anticipated. In 2021, the age group 80 years or older will comprise 5.0% of the population and account for 47.6% (model 1) to 53.6% (model 2) of stroke survivors, and in 2051, the corresponding figures will be 11.0% and 60.4%-62.9%. These significant increases

TRENDS IN STROKE SURVIVAL INCIDENCE RATES

in age-specific prevalence of stroke survivors will lead to increases in the demand for health care and costs, including the need of rehabilitation and long-term care beds. The association between older age and a poorer short- and long-term poststroke prognosis is well documented.^{40,73,74} More disabled stroke survivors and a very substantial economic burden might be expected as long-term costs account for about 80% of total stroke costs,^{75,76} although in the first year poststroke 30%-50% of the costs fall on acute hospitalization.^{76,77}

It was estimated that in Australia, the cost of treating 1 stroke patient in the first year after the event is approximately AU \$18,956 (US \$14,361),⁷⁸ the lifetime costs per first-ever case for ischemic stroke is AU \$57,106 and for ICH stroke AU \$49,995,⁷⁹ and the total health-care expenditure on stroke in 2004-2005 was AU \$546 million.⁷² In Sweden, the average lifetime cost per individual is €84,500⁷⁷ and in United States US \$103,576.⁸⁰ Despite variations in the published costs of stroke between countries, data from Australia and other developed countries are comparable. In Australia, New Zealand, and Canada, the mean total cost (per case), during the first year after a first-ever stroke, was estimated at US \$16,762⁸¹ and in 30 European countries (on average) €21,000.⁸² Based on the mean stroke costs in Australia during the first year after the event, we estimated that expenses from increase of new stroke victims would increase the financial burden to the society by 35.5% (model 1) to 59.3% (model 2) in 2021 and by 161.3%-436.2% in 2051 compared with 2011.

In coming decades, stroke burden will continue to shift away from premature death to years lived with disability.^{83,84} Stroke survivors care may constitute a significant economic challenge for the health-care system in Australia and worldwide. The NSS is expected to rise globally from 62 million in 2005 to 67 million in 2015 and 77 million in 2030,⁴ and on average, the duration of survival after first-ever stroke is estimated to be 8.2 (women) to 9.0 (men) years.¹⁸ Therefore, prevention of stroke-related disability and improving survivorship care may become more important.^{15,54,84} More research is needed to better understand the projected burden of the disease on patients, families, the health-care system, and society as a whole and properly address the issue of needs and costs when resources are scarce. The goals are to develop new preventive and treatment approaches that will significantly decrease the number of stroke victims and to improve the acute and long-term poststroke care that may markedly reduce the number of disabled persons. A co-ordinated plan of action of policy makers, health providers, and researchers to address the challenges of this debilitating disease with long-term consequences is warranted.

Strength and Limitations

The present analysis was undertaken on data collected continuously over an 11-year period and included all

patients hospitalized with a stroke in a well-defined region. Corrections for recurrent strokes, double counting, standardization, and evaluation of incidence trends by models that combine patients' age and period of the event are other strengths of the study. Several limitations to our study should be considered. First, there is some potential for missing cases, especially of out-of-hospital strokes and patients who died at home. However, the number of non-hospitalized stroke survivors should be minimal as in ACT any patient with symptomatic stroke can be admitted only to 1 of 2 public hospitals, the stroke admittance rate in ACT (as in other Australian states^{12,39,41}) is high, and ACT has a well-established full-time medical emergency and transport system. Second, we have not evaluated the incidence trends of stroke survivors in regard to stroke subtypes and stroke severity because of small numbers. Third, the study was conducted in an area with a predominantly white population, limiting the generalizability of our findings. Fourth, we used observed trends in incidence rates of stroke survivors in 1999-2000 to 2009-2010 in the ACT as the basis to make projections for the future. Although this is a reasonable approximation, data may be not sufficient to predict the future NSS accurately. Clearly, the main limitation to such extrapolation-based projections is that they cannot take into account unforeseen changes either in future incidence and mortality rates nor in demographics and in a variety of confounding social and political events. Socioeconomic and ethnic differences between Australian states and territories also add uncertainty to the predictions. Thus, our forecasts, which are based on currently available data and reflect the implications of recently observed trends on future health trajectories and disease burden, may provide a realistic long-term perspective but should be interpreted cautiously.

Conclusions

Our study demonstrates favorable trends in stroke survivor rates of older (≥ 60 years) patients in Australia in the first decade of the new millennium and projects in the foreseeable future significant increases in the absolute numbers of stroke survivors, especially among those aged 70 years or older and men. There is an urgent need to improve stroke prevention and treatment efforts to decrease the projected social and economic disease burden.

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